Air Quality National Program 203 FY2006 Annual Report

Introduction

Air Quality refers to the combination of the physical, chemical and biologic constituents of air masses in the lower atmosphere with which humans, animals, plants, lands and water bodies of the earth interact. The mission of the ARS Air Quality Research Program is through research, to 1) understand the processes of air pollution emissions from agricultural enterprises and the effects of air quality upon agriculture, 2) develop and test control measures, and 3) provide decision aids that will be useful in minimizing and reducing agricultural air pollution emissions and predicting and mitigating the impacts of air quality upon agriculture. Additional ARS air quality research focused on controlling emissions from animal production operations is conducted under the Manure and Byproduct Utilization National Program NP206.

ARS researchers collaborate with scientists and engineers outside their own management units and with engineers and scientists from universities and industry. This leverages the resources and technologies of multiple investigators to meet the challenges of understanding and reducing agricultural impacts on air quality and the effects of air quality on agriculture.

Particulate Emissions

The objective of this research component is to develop agricultural technologies and practices that minimize contamination of the air by particulates generated during production and processing of food and fiber and provide science-based technology for sound policy and regulatory decisions.

An Agricultural Air Quality Task Force (AAQTF) is appointed every 2 years by the Secretary of Agriculture to provide input to USDA research on air quality. Measurement and control of particulate matter (PM) has been a high priority for the AAQTF. A considerable amount of ARS research is focused on development of measurement technology as the unique environments and activities of agricultural systems create challenges for measuring emissions. Process models of emissions can be developed given an understanding of the basic measurements. The models are often used to develop decision support tools and emission mitigation technologies.

A new technology was collaboratively developed to improve measurement accuracy for agricultural aerosols. Research has shown that devices for sampling aerosols over-sample agricultural particulate matter, thus biasing measurements that may be used by regulatory agencies. ARS scientist at the Cropping Systems Research Laboratory in Lubbock, Texas working cooperatively with the USDA Cotton Production and processing Research Unit in Lubbock, Texas, the USDA Southwester cotton Ginning Research Laboratory at Mesilla Park, New

Mexico and the Center for Agricultural Air Quality Engineering and Science at Texas A&M University developed a new sampling head that reduces errors and provides a more accurate particulate matter concentration measurement. The device enables better measurement and monitoring of particulate matter from agricultural sources and will contribute to efforts to assure that agricultural industries are properly regulated.

A comprehensive field study was conducted during late summer 2005 by ARS scientists from the National Soil Tilth Laboratory (NSTL), Ames, Iowa, for three weeks at a confined animal feeding operation (CAFO) facility in central Iowa to measure particulate and gas emissions and dispersion. Particulate LiDAR's were deployed as a component of the study by the University of Iowa and the Space Dynamics Laboratory (SDL), Utah State University. This study incorporated new technology (LiDAR and sonic anemometry) not previously applied to CAFO's. Additionally a new particulate LiDAR has been developed by SDL. This study is the first of its kind to combine advanced LiDAR technology, sonic anemometry (turbulence measurements) as well as new techniques for measuring trace gases of ammonia, nitrous oxide and methane in a whole facility monitoring effort. Results show that data from a LiDAR scan over a dairy facility can be used to pinpoint emission sources, derive fractions for different PM sizes and determine the flux of PM from the source.

As a part of this study, an archive of field measurements for nitrous oxide and methane was extended to three consecutive years. An open-path Fast Fourier Transform Infrared Spectrometer (FTIR) unit for gas concentration measurement was deployed and evaluated for sensitivity of ammonia and other gases. This unit was also deployed during 2006 around a swine facility. The open-path FTIR has been modified since FY2005 to function properly when exposed to the extreme temperatures, wind, and humidity that occur in the summer around swine confinement facilities. The unit was used to collect data over a 3 week period.

ARS researchers at NSTL also conducted wind tunnel experiments to better understand dispersion of emissions. Models of swine housing units and manure storage facilities (approximately 1/300th scale) were placed in the control section of the wind tunnel to simulate a wide array of possible arrangements. A trip fence, spire vortex generators, and vinyl mat covering on the floor of the control section were used to create a representative surface boundary layer. A 3D hot film anemometer system was used to measured airflow characteristics at 3 distances downstream of the model buildings. Smaller and less persistent turbulent wake zones were observed downstream from swine housing unit models oriented parallel to the airflow. By contrast, models oriented perpendicular to air flow created a wake zone 5 times the building height that persisted beyond 10 times the building height downstream. The wind tunnel methods are proving to be useful tools for determining the impact of the physical layout of agricultural facilities on the dispersion of emissions.

A 2-D particulate LiDAR was developed by SDL and field tested in the late summer of 2005 at CAFO facility in central Iowa. Particulate plume emission and dispersion were measured, LiDAR sensitivity and calibrations were conducted, and 2-D image of plume dispersion were measured and evaluated. High frequency turbulence was measured in the approach, within building complex and recovery space surrounding the CAFO. A first year data set has been acquired where LiDAR measurements of particulate dispersion can be correlated with high frequency turbulence data that will enable the evaluation of particulate and gas dispersion with local meteorological conditions. Particulate characterizations are critical to understanding the movement of odoriferous compounds from animal confinement operations. The determination and quantification of these compounds will aid in developing technologies to reduce the emissions. The FTIR will provide data and the vapor phase concentrations of these compounds.

Size and concentration of dust particles in the air inside and around dairies on the Southern High Plains are not well documented. An ARS microbiologist at the Conservation and Production Research Laboratory, Bushland, Texas, conducted a study to evaluate particulate matter concentrations (eight days at each dairy) at the boundary fences, commodity barn, compost windrow fields, and milking parlor of four large dairies. The PM2.5 and PM10 particulates were collected and analyzed with various aerosol monitors. Results indicated that during most sampling events the dairies studied were in compliance with EPA regulations for particulates although, occasionally, dust concentrations near the commodity barn exceeded EPA regulations.

Efforts to improve land-use practices to prevent contamination of air and surface water resources with soil sediment are limited by their capacity to identify the primary sources of eroded sediment. ARS scientist at the Land Management Water Conservation Research Unit at Pullman, Washington determined that fatty acid methyl ester (FAME) analysis was more useful for identifying the source of wind-eroded soil that other soil community analyses. It was most recently determined that the season during which soil was collected determined the success of identifying the source of eroded sediment. The research further confirms that FAME analysis holds promise for identifying the primary source of sediment in air and surface waters and may provide an important tool that can be used to identify locations on landscapes most vulnerable to erosion, and validate wind erosion models.

A landscape perspective was also used by ARS researchers during development of a procedure that uses remote sensing of soil surfaces to identify locations affected by rainfall and wind erosion. There is a need to distinguish locations on agricultural landscapes that have been modified by rainfall from those that have been disturbed by wind erosion. Measurements of different wavelengths of light reflected from three soils modified by applying artificial rainfall and then abrading the soils with sand in a wind tunnel were made by ARS scientists at the Wind Erosion and Water Conservation Research Unit at the Cropping Systems Research Laboratory in Lubbock, Texas. Analysis of the reflectance were used to successfully identify the difference of soil texture (relative amount of sand, silt and clay particles in the soil), the occurrence of a soil crust created by the artificial rainfall, and the presence of loose sand on the crust surface that could easily be blown away by wind. The results have the potential for improving our understanding of soil properties, and identifying and measuring erosion on a global scale if successfully extended to fields, watersheds, and landscapes with the aid of earth-observing satellite systems.

Ammonia and Ammonium

The objective of the Ammonia and Ammonium Research Component is to develop systems to reduce ammonia emissions from cropping and animal production systems while improving productivity

Ammonia emitted from beef cattle feedyards represents a loss of nitrogen and fertilizer value from manure and can negatively impact the environment locally and regionally. ARS researchers from the Conservation and Production Research Laboratory, Bushland, Texas, in collaboration with researchers from the University of Alberta, Edmonton, Canada, and the Texas Agricultural Experiment Station in Amarillo, Texas, used a Lagrangian Stochastic model, a box model, the flux gradient micrometeorology method, and a nutrient balance method to measure ammonia emissions from a commercial feedyard. In general, ammonia nitrogen emissions measured from a 50,000-head feedyard were similar using all four methods and averaged 44 to 60% of fed nitrogen during the summer and 15 to 40% of fed nitrogen during the winter; on an annual basis, ammonia emissions for this feedyard averaged 14.4 kg/head capacity, with 48% of fed nitrogen lost as ammonia. These are the most comprehensive measurements of feedlot ammonia emissions currently available for use by scientists, the industry, and regulators, and will lead to a better understanding of ammonia emission from High Plains feedyards. These measurements will allow emission models/factors to be developed based on a wide range of seasonal and environmental conditions. Cattle feeders and regulators could potentially benefit from more accurate, scientifically determined emission rates.

ARS research emphasizes the importance of understanding the processes leading to emissions from agricultural operations. A final product of the knowledge that results from the research is often a computer simulation model that can be used to test the effects of different management strategies on emissions. For example, ARS scientists at University Park, PA are continuing to develop a process-based model to quantify gaseous emissions from dairy facilities and the effects of management on the emissions. The model is linked with a larger farm model used to evaluate management effects on ammonia emissions and their interaction with other nutrient losses, farm performance and farm profitability. Comprehensive models such as this will provide decision support tools for producers seeking to optimize production with reduced air and water quality impacts.

Reduction of ammonia emissions was the focus of several investigations by ARS researchers working to improve poultry production technologies. Ammonia emissions from broiler litter can cause health problems for the flock and farm workers, as well as detrimental effects on air quality. Cooperative research with the University of Maryland Eastern Shore focused on the effect of adding a superabsorbent polymer to poultry litter, at 0% and 6% of the litter by weight. Three consecutive flocks of broilers were grown-out in floor pens using the treated and untreated litter. Weekly litter samples were collected from all flocks and ammonia losses were estimated from ammonia emissions from the litter samples after placing them in a small chamber with controlled air flow. Results showed that, compared to the control, the superabsorbent polymer reduced ammonia output 70% in the first flock, 51% in the second flock, and 0% in the third flock. Production parameters such as weight gain and feed efficiency were not affected by the polymer. These results show that a 6% addition of superabsorbent polymers to broiler litter can effectively reduce ammonia emissions from broilers for two flocks. These results are of interest to researchers and policy makers who will be considering methods to reduce ammonia emissions from broiler production.

Scientists from the Poultry Production and Product Safety Research Unit in Fayetteville, AR, developed and tested an ammonia scrubber that removes ammonia and dust from air exhausted from poultry facilities. This system utilizes a dilute alum solution to captured ammonia nitrogen that would otherwise be lost to the atmosphere. This nitrogen can be utilized by the farmer to grow crops. The aluminum in the solution has the added benefit of reducing soluble phosphorus in soils, which will reduce phosphorus runoff. ARS has applied for a patent for this technology.

Malodorous Compounds

The objective of the malodorous compounds component research is to develop practices and technologies for animal production systems that minimize gaseous and particulate emissions and human health impacts and provide information for science-based policy and regulation decisions

Research to minimize malodorous compounds is challenging because of the variable nature of odor perception by humans and the typically small amounts of material present among other emissive compounds responsible for many odors. Technology for objective measurement of odorous compound production correlated to the human detection of odor is a desirable tool for research and monitoring of malodorous compounds. Volatile emissions from finishing cattle manure was assessed by ARS scientists at Clay Center, NE using a volatile emission chamber developed by them. In addition to analysis of emissions by gas chromatography/mass spectroscopy (GCMS), the gaseous emissions collected from the chamber were also analyzed by a trained olfactory panel. It was determined that there was a positive correlation between the total ionizable current generated on the GCMS (an indicator of total volatiles released from manure) and the intensity of odor detected by the panel. There was also a correlation between total ionizable current and the panel assessed hedonic tone. This provides support of the volatile emission chamber as a relatively quick and inexpensive method to assess the odor of finishing cattle manure.

ARS researchers at Bowling Green, KY developed a flux chamber method for measuring greenhouse gas, odor compound and ammonia emissions from manure-impacted environments using very inexpensive components. This technology was transferred to other emission researchers through the publication of a technology note. This flux chamber method is currently being used to measure greenhouse gas emissions from beef cattle feedlot surfaces and manure stockpiles. It has also been adapted to compare odor compound emissions from different manures, thus expanding measurement options for research and potential applications technology.

ARS scientists in Bowling Green, KY also developed an equilibrium sampler for the measurement of malodorous compounds in water. This allows measurement of these compounds on site in waste lagoons, anaerobic pits and other sites on animal production facilities. Additionally, methodology has been developed for quantifying malodorous sulfides (hydrogen sulfide, methyl mercaptan, etc.) from waste slurries and microbial cultures. This methodology is being used to determine if probes developed for the quantification of sulfate reducing bacteria can be used to predict sulfide emissions from lagoons, anaerobic pits and other waste storage areas.

Ozone Impacts

The objectives of the ozone impacts research are to identify ozone-tolerant crop species and varieties, response mechanisms to select or develop tolerant varieties, and production methods that minimize ozone-induced limitations on crop production and quality; and develop science-based information required for sound policy and regulatory decisions.

Ground-level ozone concentrations are sufficient to suppress crop yields in many agricultural areas and may increase to the point where crops such as soybeans may suffer significant yield losses. Screening soybean ancestors for potential sources of ozone tolerant genes is a strategy for adaptation to increased atmospheric ozone concentrations. Thirty soybean ancestors representing a majority of genes in modern U.S. cultivars were screened for ozone sensitivity under greenhouse conditions by scientists of the ARS Plant Science Research Unit and the ARS Soybean and Nitrogen Fixation Research Unit in Raleigh, North Carolina. Two ancestors exhibited minimal ozone injury following a 5-day exposure to elevated ozone levels. If confirmed in yield tests, these ozone-tolerant ancestors represent sources of genes for development of new ozone tolerant cultivars so that productivity can be maintained under future climate scenarios where ambient ozone concentration are expected to be much higher than today.

Pesticides and Other Synthetic Organic Compounds

The objective of this research is to develop agricultural production systems that minimize unwanted emission and transport of pesticides. Note that research on alternatives to methyl bromide is conducted under National Program NP308.

Knowledge of the fate and transport of agrochemicals in both vapor and particle phases is needed to mitigate deposition on surrounding ecosystems. During spring and summer, the disturbance of surface soils from cultivation leads to an increase in the coarse sized fraction of particulates in the atmosphere of Chesapeake Bay rural areas. Research by the Environmental Management and By-Product Utilization Laboratory in Beltsville, Maryland determined that pesticide concentrations in particle phase among the particulates was much greater than would be predicted from standard vapor-particle partition models based on the physical properties of the pesticides. The tilling of fields, or even moving planting and spraying equipment through the field, prior to and during, pesticide application results in the suspension of soil particles containing aged residues of the pesticides applied during the previous years along with residues from recent applications. The results provide knowledge of pesticide fates and transport needed for development of improved agricultural practices to reduce pesticide movement to surrounding ecosystems.

Pesticide movement in soils is affected by pesticide application methods, soil and environmental conditions and water management practices. Soil diffusion models offer a means of studying pesticide fate and transport under varying management practices and environmental conditions, thus offering an additional tool for developing new application strategies. Using a new soil diffusion model that was validated with comparisons between simulated and measured values, a study by ARS scientists at the U.S. Salinity Laboratory in Riverside, California showed that surface application of triallate would lead to emissions of 80% and a soil concentration of 6% after 100 days. Alternatively, incorporating triallate to a depth of 10 cm in the soil would reduce emissions to less than 5% and result in a soil concentration of 41% after 100 days. The results suggest that different approaches to pesticide application are possible that may improve application efficiency and reduce environmental contamination.

Conclusions

ARS agricultural air quality research addresses issues relevant to crop and animal production systems. Accurate and efficient measurements are at the core of the research as the data is providing answers to what compounds are being emitted and how much is being emitted through time and space. New technologies such as the LiDAR systems and the improved sampling heads promise to provide even better characterization of emissions. The adaptation and development of models provides tools for research and the basis for decision support systems to be used by researchers, producers and policy makers. New emission reduction technologies are building upon the knowledge base that is resulting from the research.

ARS National Program Cycle and Future Status

ARS National Program Research is conducted on five-year cycles. The Air Quality Program will be entering the final year of this cycle during 2007. During 2007 an accomplishment report will be assembled for ARS Air Quality research and reviewed by a panel composed of non-ARS scientists in accordance with requirements set forth by the ARS Office of Scientific Quality Review (OSQR). This cumulative report will be posted as the Air Quality National Program progress report for 2007 activities. During 2008, a workshop will be convened to set the directions for the next cycle of Air Quality research. Administratively, the Air Quality Research Program will be merged together with the Global Change (NP204) and Soil Resources National Programs (NP202) as the Air and Soil Resources Management National Program (NP212).